Risk Factors for the Development of Contralateral Epidural Hematoma Following Decompressive Craniectomy in Patients with Calvarial Skull Fracture Contralateral to the Craniectomy Site

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■ OBJECTIVE: **To investigate the frequency and risk factors of contralateral epidural hematoma (CEDH) following decompressive craniectomy (DC) in patients with calvarial skull fracture contralateral to the craniectomy site.**

■ METHODS: **After reviewing the medical records and radiographs over a 5-year period, 72 patients with calvarial fracture contralateral to the craniectomy site were enrolled to determine the risk factors for the development of CEDH following DC.**

■ RESULTS: **Among 13 patients with CEDH following DC, all but 1 patient were younger than 60 years of age. In 10 patients (77%) with CEDH, the contralateral calvarial fracture involved more than 1 bone plate. Comparatively, contralateral calvarial fracture involving more than 1 bone plate was noted in 21 patients (35.6%) without CEDH. After multiple logistic regression analysis, only age ($P = 0.008$, odds ratio [OR] = 0.916, 95% confidence interval [CI] = 0.858−0.987) and number of fracture-involved bone plate ($P = 0.006$, OR = 10.971, 95% CI = 2.02−59.70) remained independently associated with CEDH development following DC, and CEDH development rate increased by 8.4% with every 1-year decrease in age.**

■ CONCLUSIONS: **Age and number of fracture-involved bone plate are significant risk factors for CEDH development following DC. Involvement of 2 or more bone plates of contralateral calvarial skull fracture in young adult may prompt an immediate postoperative computed tomography scan to detect the occurrence of CEDH, irrespective of the operative findings and neurologic status. This may prevent devastating neurologic consequences of CEDH and improve therapeutic outcome.**

INTRODUCTION

Decompressive craniectomy (DC) has been performed increasingly over the past years to control medically refractory intracranial hypertension in patients with severe traumatic brain injury (TBI), malignant middle cerebral infarction, and other central nervous diseases.[1-3] Although DC is a potentially life-saving procedure for patients with severe TBI, it is associated with some potential complications.[4-7] One severe complication following DC is the development of an epidural hematoma contralateral to the craniectomy site.[8-11] This delayed contralateral epidural hematoma (CEDH) may present with intraoperative brain swelling, postoperative pupillary abnormalities, intractably increased intracranial pressure (ICP), or acute neurologic deterioration.[8-11] If not diagnosed, CEDH can cause serious consequences. In some previous studies,[10-12] the presence of a skull fracture contralateral to the craniectomy site was considered a risk factor for the development of CEDH. Talbott et al. thought the calvarial fracture patterns on the preoperative computed tomography (CT) scan could predict the risk for CEDH development.[12] However, interestingly, many patients with contralateral calvarial

Key words
- Calvarial skull fracture
- Contralateral epidural hematoma
- Decompressive craniectomy
- Traumatic brain injury

Abbreviations and Acronyms
CEDH: Contralateral epidural hematoma
CI: Confidence interval
CT: Computed tomography
DC: Decompressive craniectomy
GCS: Glasgow Coma Scale
GOS: Glasgow Outcome Scale
ICP: Intracranial pressure
OR: Odds ratio
ROC: Receiver operating characteristic
TBI: Traumatic brain injury

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skull fracture did not develop CEDH following DC in clinical practice. Therefore we retrospectively reviewed a series of patients undergoing DC for acute TBI over a 5-year period. On the basis of a preoperative CT scan, patients with calvarial skull fracture contralateral to the craniectomy site were enrolled to determine the risk factors for the development of CEDH following DC. We aimed to improve the therapeutic strategy and outcome of this potentially devastating complication in patients undergoing DC for acute TBI.

MATERIALS AND METHODS

Study Design

In this study, we retrospectively reviewed the medical records of 235 patients with acute TBI who underwent DC from 2008–2012. The indication for performing DC was marked swelling of the brain after evacuation of any type of intradural hemorrhagic lesion or increased ICP refractory to medical treatment in patients with ICP monitoring. The DC procedure entailed removal of a large portion of the skull bone. The underlying dura was opened widely to accommodate the swollen brain without performing duroplasty. Among the patients, 31 patients who had incomplete medical records or lacked postoperative CT scan were excluded from the study. Additionally, patients who underwent bifrontal DC were excluded. Further, patients without calvarial skull fracture contralateral to the craniectomy site on preoperative CT scan were also excluded. Finally, 72 patients with skull fracture contralateral to the craniectomy site were enrolled to determine the risk factors for the development of CEDH following DC.

Clinical Data

For each patient, the demographic data, mechanism of head injury, neurologic examination, operative findings, clinical course, and outcome were reviewed from the medical records. The neurologic examination findings included the preoperative Glasgow Coma Scale (GCS) score and the pupillary size and reactivity. Severe TBI was defined as a GCS score of $\leq$8 following resuscitation. Time intervals from the time of trauma to the time of DC and postoperative CT scan were reviewed. Decompression time was defined as the time interval between the traumatic event and the start of DC operation plus 30 minutes, which represented an estimated time for performing DC. The reasons for postoperative CT examination were categorized as intraoperative brain swelling, postoperative neurologic deterioration, and routine examination (no change of neurologic status). Postoperative neurologic deterioration might present as postoperative pupillary dilation contralateral to the DC site or deterioration of GCS score in the postoperative period.

Functional outcome was evaluated 6 months after patient discharge by using Glasgow Outcome Scale (GOS) score as follows: 1 = death, 2 = persistent vegetative state, 3 = severe disability, 4 = moderate disability, and 5 = good recovery.[13] Outcome was categorized as favorable (GOS 4 and 5) and unfavorable (GOS 1-3) outcomes.

Radiographic Data

Preoperative CT scans were reviewed by 1 neuroradiologist and 2 neurosurgeons without the knowledge of whether the patient developed a CEDH. The calvarial skull was categorized into 5 bone plates as the frontal bone, parietal bone, calvarial temporal bone, calvarial sphenoid bone, and calvarial occipital bone. Skull fractures involving these 5 bone plates were included for analysis. However, skull base and facial bone fractures were excluded from analysis. For each patient, the number of fracture-involved bone plate contralateral to the DC site was carefully reviewed. The patterns of skull fracture were divided into fracture with calvarial temporal involvement and those without calvarial temporal involvement for analysis. In addition, the degree of midline shift and status of basal cistern were also recorded from the preoperative CT scans. Status of basal cistern was classified as normal, compressed, or absent.[14] Postoperative CT scans were examined for the presence and volume of CEDH and the size of DC. The volume of CEDH was measured by the empirical formula of volume ($0.5 \times$ height $\times$ depth $\times$ length) based on the distance measurements of the depth and the length on the CT slice with the largest clot area.[15] The size of craniectomy was calculated by assuming the craniectomy area as a hypothetical circle with diameter = d (the largest diameter calculated on CT scans).[2,16] The area (A) of the segment of a sphere above the craniectomy area was therefore calculated with the formula: $A = \pi[(d/2)^2 + h^2]$, where h represents the perpendicular line to d with the longest distance from d to the dural flap (**Figure 1**).

Statistical Analysis

Two separate statistical analyses were performed. First, the risk factors for CEDH following DC in patients with calvarial skull fracture contralateral to the craniectomy site were determined. The effects of individual variables including sex, age, underlying diseases, clinical findings, decompressive time, preoperative CT findings, and craniectomy size were analyzed by univariate

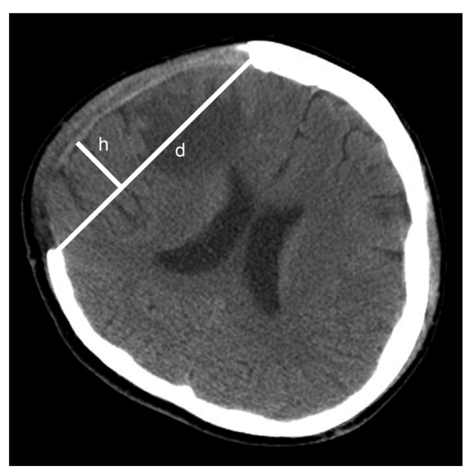

Figure 1. Craniectomy size. Axial computed tomography scan demonstrates the method used for calculation of the craniectomy size (see text for details).